IMAGE PROCESSING METHOD, APPARATUS

AND MEMORY MEDIUM THEREFOR

BACKGROUND OF THE INVENTION

5   Field of the Invention

The present invention relates to an image

processing method, an apparatus and a memory medium

therefor.

Related Background Art

10   For adjusting the color balance of a photographic

image there are conventionally known two methods,

namely:

(1) matching the color balance before picture

taking; and

15   (2) correcting the image after picture taking.

As an example of the method (1), there is known an

color balance adjusting method utilizing a white

balance switch for example of a video camera. In this

method, the white color balance of the taken image is

20   adjusted by preliminarily taking white paper or the

like before starting the main picture taking operation.

The method (2) is widely exercised for example in

the printing field, but depends on the experience and

intuition of experts.

25   On the other hand, with the recent spreading of

digital cameras and photo scanners, the digitization of

the photographic image can be easily achieved by the

general users. Also the output equipment represented
by ink jet printer is progressing toward higher image
quality and lower cost, that the general users can
easily print the photograph at home.

5   However, in case of printing a digitized
photographic image, the quality of the outputted image
is still insufficient.

        For example, for printing the RGB signals from an
input equipment by an output equipment represented by
10   an ink jet printer through so-called personal computer
or the like, there has been tried color matching
between the input equipment and the output equipment
thorough the CIE XYZ color space by Color Think (trade
name) in the Apple McIntosh or by CMS in the Microsoft
15   Windows (trade name). It is however very difficult to
execute these adjustments in strict manner, because the
color reproduction range is naturally different between
the input equipment and the output equipment, and there
is also involved a basic difference in the working
20   principle that the input equipment works on the R, G
and B light emissions while the output equipment works
on the C, M, Y and K reflective colors.

        Even if the color matching is achieved between the
input equipment and the output equipment by overcoming
25   such difficulties, the image satisfactory for the user
cannot be obtained merely by strictly reproducing the
image from the input equipment as a print if such

original image from the input equipment is not

satisfactory. Such situation arises in case of an

overexposure or an underexposure in the image taking or

a distorted color balance of the entire image caused by

5   a "color fog" phenomenon.

For example, in case of auto picture taking by a

camera with the AE (automatic exposure) function, there

results a generally dark image of so-called

underexposure state if the background of the object is

10   principally constituted by blue sky, but there results

an overexposure state if the background is principally

dark, so that the intended object is not always

recorded in a best state.

Also in case of a digital camera, the image is

15   picked up by a CCD, so that a wavelength region not

sensitive to the human eye is also contained in the

image signal. If such signal is processed as a part of

the RGB signals, the original invisible color becomes

visible to distort the color balance. Naturally there

20   is incorporated an infrared cut-off filtering but such

filtering is not necessarily complete, and the color

balance cannot be completely corrected within the

limitation of real-time processing. As a result there

is caused a "color fog" phenomenon, distorting the

25   color balance of the entire image.

Since similar phenomena may occur in the photo

scanner or the flat bed scanner, the color balance may

be distorted in the digitization with such scanner even if the original negative or reversal film is in the optimum state.

Therefore, in order to obtain satisfactory output result it is necessary to correct the input image data themselves into the image data of appropriate exposure with satisfactory color balance, and, for this purpose, there is required a simple method not requiring cumbersome operations by the user, with a sufficiently acceptable processing speed.

SUMMARY OF THE INVENTION

In consideration of the foregoing, an object of the present invention is to enable color balance correction of high-definition image data with a simple configuration.

The above-mentioned object can be attained, according to the present invention, by an image processing method of detecting the luminance of a highlight point and a shadow point of an original image, determining the chromaticity of the highlight point and the shadow point from plural pixels of the luminance, and executing a correction process on the original image based on the highlight point, the shadow point and the chromaticity: wherein the correction process executes matching of the color solid axis of the original image with an axis indicating the

luminance and contrast adjustment on a color component indicating the luminance of the original image.

Another object of the present invention is to enable judgment of the image state by a very simple method and optimum correction automatically according to such judgment.

The above-mentioned object can be attained, according to the present invention, by an image processing method comprising steps of:

detecting the color solid axis of an original image;

judging the exposure state of the original image from the positional relationship between the color solid axis and an axis indicating the luminance in a color space in which the color solid is represented; and

setting an image correcting condition according to the result of the judgment.

The above-mentioned object can also be attained by an image processing method for effecting an image correction process on an original image according to the color distribution thereof, comprising steps of:

detecting the color solid axis of the original image in a predetermined color space; and

controlling the image correction process based on the positional relationship of the color solid axis in the color space.

Still other objects of the present invention, and
the features thereof, will become fully apparent from
the following detailed description, which is to be
taken in conjunction with the attached drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of an image processing
apparatus;

Fig. 2 is a block diagram of a printer driver;

10 Fig. 3 is a flow chart showing the control
sequence of an image correction process unit;

Fig. 4 is a flow chart showing the sequence of
preparing a luminance histogram;

Figs. 5A, 5B and 5C are schematic views of a color
15 solid indicating the distribution of luminance and hue;

Fig. 6 is a chart showing a non-linear gamma
conversion function;

Figs. 7A, 7B, 7C and 7D are charts showing
features of overexposure and underexposure on a
20 luminance-saturation plane, wherein Fig. 7A is a chart
showing the concept of an overexposure; Fig. 7B is a
chart showing the concept of an underexposure; Fig. 7C
is a chart showing an example overexposure; and Fig. 7D
is a chart showing an example of underexposure;

25 Fig. 8 is a chart showing the manner of
determining the color solid axis in a third embodiment;

Fig. 9 is a flow chart showing the control

sequence of image correction; and

Fig. 10 is a flow chart showing the control
sequence of color fog correction in a second
embodiment.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now the present invention will be clarified in
detail by preferred embodiments thereof with reference
to the attached drawings.

10   [First Embodiment]

In the image processing method of the present
embodiment, the original RGB image data are converted
into luminance and chromaticity data indicating the
brightness and the hue for each pixel. In this

15   operation the pixels are selected in succession,
skipping a pixel for which the saturation of the
original image data exceed a predetermined value, and a
luminance histogram is prepared. Then the luminance
positions (luminance values) for which the cumulative

20   numbers from the high and low luminance sides reach
respectively predetermined values are determined as a
white position (highlight point) and a black position
(shadow point). In this operation, in order to improve
the accuracy of detection of the white and black

25   positions, there may be adopted a process of excluding
the high saturation pixels from the luminance
histogram.

Then there are calculated the average value of the chromaticity of the pixel data having the luminance value identified as the white position and the average value of the chromaticity of the pixel data having the

5 luminance value identified as the black position, and a straight line connecting these points in the color space is identified as the color solid axis (gray line). The inclination of the color solid axis with respect to the luminance axis indicates that the color

10 solid axis which should original indicate the change in the luminance only includes a change in the chromaticity, namely that there is generated a color fog. The color fog is corrected by executing a conversion process (rotational matrix calculation) on

15 all the pixels in such a manner that the color solid axis assumes the normal position in the above-mentioned color space. In the following the present embodiment will be explained in further detail with reference to the attached drawings.

20 [Configuration of image processing system]

An example of the system in the present embodiment is shown in Fig. 1. For example a printer 105 such as an ink jet printer and a monitor 106 are connected to a host computer 100. The host computer 100 is provided

25 with an application software 101 such as a word processor, a table calculation, an internet blouser etc., an operating system (OS) 102, a printer driver

103 for preparing print data by processing various drawing commands (image drawing command, text drawing command, graphics drawing command etc.) indicating an output image issued by the application 101 to the OS

5   102, and a monitor driver 104 for displaying on the monitor 106 by processing various drawing commands issued by the application 101.

The host computer 100 is provided, as the hardwares for operating these softwares, with a central

10   processing unit (CPU) 108, a hard disk driver (HD) 107, a random access memory (RAM) 109, a read-only memory (ROM) 110 etc.

As an example of the image processing system shown in Fig. 1, there can be conceived a configuration

15   employing a personal computer compatible with PC-AT of IBM and Windows 95 of Microsoft as the operating system, installing a desired application for executing printing and connecting a monitor and a printer.

In the host computer 100, based on an image

20   displayed on the monitor, an application 101 prepares output image data utilizing text data classified as a text such as a character, graphics data classified as graphics and image data classified as a natural image. For printing the output image data, the application 101

25   sends a print output request to the OS 102 and sends thereto a group of drawing commands consisting of graphics drawing commands for the graphics data and

image drawing commands for the image data. In response
to the output request from the application, the OS 102
issues the drawing command group to a printer driver
103 corresponding to the output printer. The printer

5   driver 103 prepares print data, printable by the
printer 105, by processing the print request and the
drawing command group entered from the OS 102 and
transfers such print data to the printer 105. In case
the printer 105 is a raster printer, the printer driver

10   103 executes an image correction process in succession
on the drawing commands from the OS, then executes
rasterization into a page memory having a capacity of
24 bits for the RGB signals, then, after the
rasterization of all the drawing commands, converts the

15   content of the page memory into a data format printable
by the printer 105, for example CMYK data, and
transfers the converted data to the printer.

The process executed in the printer driver 103
will be explained with reference to Fig. 2.

20   In the printer driver 103, an image correction
process unit 120 executes an image correction process
to be explained later, on the color information of the
image drawing commands contained in the drawing command
group entered from the OS 102. A correction process

25   unit 121 for printer rasterizes the drawing commands,
utilizing the color information subjected to the image
correction process, thus generating dot image data on

the RGB 24-bit page memory. Then it executes masking, gamma correction, quantization etc. for each pixel according to the color reproducibility of the printer, and generates and sends the CMYK data dependent on the

5 printer characteristics to the printer 105.

[Image Correction Process Unit]

In the following there will be explained, with reference to Figs. 3 to 7D and 9, the process executed in the image correction process unit 120 on the

10 original image represented by the image drawing commands. The following process is not executed on the original image represented by the graphic drawing commands or by the text drawing commands.

The image correction process unit 120 of the

15 present embodiment executes, as shown in Fig. 3, a histogram preparation process (S20) and an image correction process (S30) according to the histogram. The step S20 prepares a histogram by a process shown in Fig. 4, and the highlight point and the shadow point of

20 the image are determined from thus prepared histogram.

[Preparation of Luminance Histogram]

Fig. 4 is a flow chart showing the preparation of luminance histogram in the present embodiment.

Referring to Fig. 4, a step S1 initiates the

25 routine for preparing the luminance histogram of the original image. A step S2 determines the ratio of selection of the pixels to be used for preparing the

luminance histogram from the pixels of the original image. In the present embodiment, the luminance histogram is prepared from all the pixels (selection ratio 1 (or 100%)) in case the image data to be

5   processed have 350,000 pixels. In case the entered image data have a number of pixels larger than 350,000 pixels, the pixels are selected (sampled) according to the ratio of the total number pixels to 350,000 pixels. For example if the input image data are of 3,500,000

10   pixels, the selection ratio is 3,500/350 = 10, so that the luminance histogram is prepared at a rate of one out of 10 pixels (selection ratio 10 or 10%). In the present embodiment, the selection ratio is determined from the following formula:

15   n = int(total pixel number of object image data/350,000)

(however, if n < 1, n is selected as 1, and n being a positive number)

Then a step S3 resets a counter for managing the

20   line number or sets it at a predetermined initial value, and a step S4 increases the content of the counter to a line number of the object line.

In the present embodiment, the sampling of the pixels is executed in the unit of a line. Therefore,

25   for a selection ratio n, the line number is divided by n, and, if the remainder is 0, the pixels belonging to such line are selected for processing (S5-YES). For

example, for a selection ratio 10, the line number is divided by 10 and, if the remainder is 0, the pixels belonging to the line are selected for processing.

If the object line is to be skipped and not to be processed, the sequence returns to the step S4. If the object line is to processed, the sequence proceeds to a step S6, and the pixels belonging to such line are subjected to luminance conversion and chromaticity conversion in succession. In the present embodiment, the luminance conversion and chromaticity conversion are executed according to the following equations. However such conversion are not limited to these equations but can also be achieved by various equations:

$$Y \text{ (luminance)} = int(0.30R + 0.59G + 0.11B) \quad (Y \text{ being positive})$$

$$C1 \text{ (chromaticity)} = R - Y$$

$$C2 \text{ (chromaticity)} = B - Y$$

Also in the present embodiment, in order to improve the accuracy of detection of the white position (highlight point) and black position (shadow point), the saturation S of an object pixel is calculated by the following equation and is compared with a predetermined saturation value (Sconst)(S7), and, if the saturation S is larger, the information of such pixel is not reflected in the luminance histogram:

$$\text{Saturation } S = sqrt(C1^2 + C2^2)$$

wherein sqrt(x) is a function giving the square root of x, and x^y means x to a power y.

Thus, in case S > Sconst, the sequence returns to the step S6 and the data of the object pixel are not reflected in the succeeding process. This is because, as will be explained later, the saturation of the white position is given by the average saturation of a group of pixels of high luminance and such saturation indicates an error caused by the color fog, so that the pixels assumed as of originally high saturation had better be eliminated from the calculation of the highlight point. The effect of this process will be explained by a specific example. For example a yellow pixel (R = G = 255, B = 0) has a luminance Y = 226 and a saturation S = 227 according to the foregoing equations. Thus, this pixel has an extremely high luminance and a sufficiently high saturation. Such pixel should be considered as originally yellow in most cases, rather than considered as generated by yellow color fogging of an originally colorless pixel. If the pixel of such high luminance and high saturation is included in the luminance histogram, an error is generated in the detected white position. Therefore, in the present embodiment, there is determined a certain saturation (Sconst) and the pixel of which saturation exceeds such predetermined saturation is not included in the luminance histogram. Such method

allows to prevent the error caused by the pixels of high saturation in the detected white position, thereby improving the accuracy of the white position.

After such discrimination in the step S7, the luminance histogram is prepared on the pixels satisfying the condition $S \leq Sconst$ (S8). As the pixel data employed in the present invention have 8 bits (256 density levels) for each of RGB data, the luminance is also converted into 256 levels. Consequently the luminance histogram is obtained by counting the frequency of pixels in each of 256 luminance levels.

Also in the present embodiment, the calculated chromaticity values C1, C2 are retained in the following manner since they are used for calculating the average chromaticity of the pixels of each luminance level, in the color fog correction to be explained later. In structurally arranged variable with an index from 0 to 255, the frequency, cumulative C1 value and cumulative C2 value are set as three members and the result of calculation for each pixel is reflected in a member having the index corresponding to the luminance value of the pixel.

When the process on the object pixel is completed, there is discriminated whether all the pixels in the object line have been processed (S9), and, if any unprocessed pixel remains in the object line, the sequence returns to the step S6 to repeat the process

thereafter. When all the pixels in the object line have been processed, a step S10 discriminates whether any line remains unprocessed, and, if all the lines have been processed, a step S11 terminates the sequence, but, if any unprocessed line remains, the sequence returns to the step S4 and the above-described process is repeated with the object line shifted to a next line.

The preparation of the luminance histogram with the selection of the pixels of the original image data in the above-described manner allows to obtain a histogram with a minimum necessary number of pixels and with consideration of improvement in the accuracy in the detection of the white and black positions afterwards.

[Determination of White Position (Highlight Point) and Black Position (Shadow Point)]

After the preparation of the luminance histogram, it is used for determining the white position (highlight point) and the black position (shadow point). In the present embodiment, the black and white positions are defined as points where the cumulative luminance frequency reaches 1750 from both ends (luminance value 0 and 255) of the luminance histogram toward the center thereof.

More specifically, the frequency PY of the pixels of a luminance value Y is cumulatively added as $P0 + P1$

+ ... and the luminance value when the cumulative frequency reaches 1750 is defined as the luminance value YSD of the black position. Then there is calculated the average chromaticity of the pixels of the luminance YSD. As explained in the foregoing, the cumulative values of chromaticity for each luminance value are calculated at the preparation of the luminance histogram (cumulative chromaticity values C1Ntotal, C2Ntotal for pixels of luminance N), so that the average chromaticity values C1SD, C2SD of the pixels with the luminance value YSD corresponding to the black position are determined by the following equations:

C1SD = C1YSDtotal/PYSD

C2SD = C2YSDtotal/PYSD

The white position is similarly determined by calculating the cumulative frequency P255 + P254 + ... and the luminance value where the cumulative frequency exceeds 1750 is defined as the luminance YHL of the white position. Then calculated are the average chromaticity values C1HL, C2HL of the pixels of the luminance YHL in the following manner:

C1HL = C1YHLtotal/PYHL

C2HL = C2YHLtotal/PYHL

The above-described calculations allow to determine the white position (C1HL, C2HL, YHL) and the black position (C1SD, C2SD, YSD) in the (C1, C2, Y)

color space.

In the present embodiment, the cumulative frequency is determined from the luminance positions of the luminance values 0 and 255, but there may be given

5   a certain offset such as determination from the luminance values 1 and 254.

As explained above, a step S20 in Fig. 3 determines the white position (highlight point) and the black position (shadow point).

10   Then a step S30 in Fig. 3 executes an image correction process, based on the white and black positions determined in the step S20. The image correction process in the present embodiment includes color fog correction for correcting the color fog in

15   the original age, exposure correction for correcting the luminance contrast for optimizing the exposure of the original image, and saturation correction for improving the color appearance of the output image.

Fig. 9 shows the flow of correction process

20   executed by the image correction process unit 120 in the step S30 in Fig. 3. At first a rotation matrix for color fog correction is determined, then color balance (color fog) is corrected by the rotation matrix, and the gamma conversion is executed for the luminance

25   signal according to the exposure status of the image. These steps will be explained in succession.

[Color Fog Correction]

After the above-described determination of the
white and black positions of the original image in the
(C1, C2, Y) color space, the color fog correction is
executed.

5   If the original image is an ideal image without
color fog, R = G = B on the colorless axis and the
calculated chromaticity values for the white and black
positions should satisfy C1HL = C2HL = C1SD = C2SD.
However, in the presence of a color fog, the line

10   connecting (C1HL, C2HL, YHL) and (C1SD, C2SD, YSD),
namely the color solid axis, shows an inclination
toward the color of such color fog, in proportion to
the level of the color fog. The color fog correction
can be achieved by a conversion in such a manner that

15   the color solid axis coincides with the Y-axis
(luminance axis). The conversion may be achieved by
rotation and parallel translation of the color solid,
or by conversion of the coordinate system.

In the present embodiment, the color solid of the

20   original image is at first rotated, taking the minimum
luminance point (lowest point) of the color solid axis
as the center of rotation, until the color solid axis
becomes parallel to the Y-axis. Then the coordinate
system is converted in such a manner that the above-

25   mentioned minimum luminance point becomes the original
point of the (C1, C2, Y) space. After such color fog
correction, the color solid shown in Fig. 5B becomes as

shown in Fig. 5C. The conversion provides a result having the original point at the minimum luminance point and the color solid axis coinciding with the Y-axis. Fig. 5A shows a color solid of the image data

5   having an ideal color distribution without color fog. The above-described conversion brings the color solid after conversion (Fig. 5C) close to the ideal color solid (Fig. 5A).

In the rotation for bringing the color solid axis

10   parallel to Y-axis, the axis and angle of rotation can be easily determined from the coordinate values of the shadow and highlight points. The method of determining the rotation matrix for rotating a solid in a three-dimensional space by a desired angle about a desired

15   axis is already known and will not be explained in detail.

The color fog correction can be corrected, as explained in the foregoing, by converting each pixel of the original image into pixel data (C1, C2, Y) in the

20   three-dimensional color space represented by chromaticity values and luminance, and applying rotation and parallel translation to such pixel data to obtain pixel data (C1', C2', Y) for which the color solid axis (gray line) connecting the black and white

25   positions coincides with the Y-axis and the minimum luminance point is at the original point of the coordinate system.

[Adjustment of Contrast and Saturation]

In the following there will be explained a method, for further improving the quality of the image by adjustment of contrast and saturation, of judging the over/underexposure state of the image in a simple manner and accordingly applying gamma correction to the luminance signal.

The contrast adjustment is executed by adjusting the luminance of the black position (shadow point) to "0" or a value close thereto (for example "10") and that of the white position (highlight point) to "255" or a value close thereto (for example "245").

In the following there will be explained an embodiment of judging the over- or underexposure state of the image exposure in a simple manner and accordingly applying gamma correction to the image data.

At first there are determined points T, T' in Fig. 5B, showing the minimum distance between the color solid axis to be corrected and the luminance (Y) axis. These points can be easily determined from the geometrical relation.

Then the contrast is so adjusted that the luminance component YT' of the point T' after the color fog correction becomes equal to the luminance component YT of the point T. As shown in Fig. 6, a point (YT,YT') is taken as an inflection point, and, if

luminance Y' after the color fog correction is smaller

than YT', the luminance is corrected to Y" by a

function given by a straight line a, and, if it is

larger than YT', the luminance is corrected to Y" by a

5   function given by a straight line b.

Naturally there may be executed a correction

indicated by a line 12 in Fig. 6, without using T, T'.

If the color solid axis is parallel to the luminance

axis, the point pair T, T' is not uniquely determined,

10   and, if T, T' are positioned outside the luminance

range (0, 255), the point (YT, YT') cannot be taken as

the inflection point. In such special case, the

correction can be made according to the line 12.

The correction utilizing the closest points T, T'

15   of two axes becomes effective particularly on the image

involving over- or underexposure. The overexposure is

induced by a fact that the exposure for the enter image

is influenced by a lighter area such as sky. In such

situation the input device represented by a digital

20   camera executes suppression of the color of high

luminance, reducing the saturation of the high

luminance area. As will be understood from the color

solid axis of the image subjected to such suppression

of the color of high luminance, represented on a

25   saturation-luminance two-dimensional plane shown in

Fig. 7A, the pixel closest to gray appears in the high

luminance area. On the other hand, for an

underexposure image, the saturation becomes lower in the low luminance area as shown in Fig. 7B, because of the suppression of the color of low luminance.

In the actual image, the luminance axis of the color solid assumes a form shown in Fig. 7C for an overexposed image, on the luminance-saturation plane. On the other hand, an underexposed image assumes a form as shown in Fig. 7D. If the actual color solid is considered to be displaced from the original color solid in the ideal state by the influence of image taking conditions or input conditions at the A/D conversion, the points T, T' are considered to indicate the positions of minimum displacement. In the present invention such displacement is eliminated to obtain appropriate gray in a simple manner, thereby correcting the brightness level of the entire image.

It is naturally possible also to use T solely as means for simply judging the over- or underexposure state of the image, prepare look-up tables (LUT) for the under- and overexposure states and execute the gamma adjustment of the luminance signal according to the luminance component of thepoint T or T'. For example the contrast adjustment may be made with a curve having an inflection point at (YT, YT') in Fig. 6. It is thus possible to simply judge, by the values of T, T', whether the image is over- or under exposed. Stated different, the luminance component of the point

T', showing the lowest saturation on the color solid axis, is positioned at the high luminance side, the image shows a luminance-saturation relationship as shown in Fig. 7A, and, if the luminance component of the point T' is at the low luminance side, the image shows a luminance-saturation relationship as shown in Fig. 7B. Therefore, in an image subjected to the suppression of the color of high luminance and low luminance, the image is considered in an overexposure state or in an underexposure state if the luminance component of the point T' is respectively at the high luminance side or at the low luminance side.

On the other hand, the saturation can be easily adjusted by multiplying the color differences C1, C2 with saturation correction coefficients. As an example, for an increase of the saturation by 20% a saturation correcting coefficient of 1.2 is adopted, and the saturation can be corrected by:

C1" = 1.2 × C1'

C2" = 1.2 × C2'

because the saturation is defined by:

Saturation = sqrt(C1^2 + C2^2).

[Inverse Conversion to RGB Space]

The corrections in the present embodiment are completed as explained above. In this state, each pixel of the original image is converted from the (R, G, B) color signal data into (C1", C2", Y") color space

data, which have to be inserve converted into (R', G', B') color signal data according to the following equations:

$$R' = Y'' + C1''$$

5      $$G' = Y'' - (0.3/0.59) \times C1'' - (0.11/0.59) \times C2''$$

$$B' = Y'' + C2''$$

In this manner there can be obtained RGB data which are corrected from the original image in the color fog, contrast and saturation.

10   As explained in the foregoing, the present embodiment enables secure correction of the color fog with limited load of processing.

Also in the present embodiment, as the sampling condition is selected according to the image data size

15   of the original image, there can be maintained a substantially constant relationship between the entire frequency in the histogram and the cumulative frequencies for determining the white and black positions, regardless of the input image. Consequently

20   there can be realized satisfactory color fog correction.

In addition, by executing the non-linear gamma correction on the entire image so as to maintain the luminance at a point where the axis of the color solid

25   of the image to be corrected is closest to the luminance axis, there can be achieved contrast correction while maintaining the luminance presumably

closest to that of the original image.

Furthermore it is possible to easily obtain the over- or underexposure state of the image, and to apply a gamma correction by selecting a table according to such exposure state.

The pixel sampling may also be executed in the unit of a column instead of the unit of a line.

[Second Embodiment]

In the following there will be explained a second embodiment, which takes the level of correction into consideration with respect to the first embodiment.

As explained in the first embodiment, if the axis of the color solid determined from the image shows an excessively large inclination, the correction of such axis may result in the deterioration of the image quality. Such situation may arise in case, for example, the color fog is intentionally caused by the use of a color filter, or the image is taken under the sunset environment.

In such case, such drawback can be avoided by judging that the determined highlight and shadow points are erroneous and not executing the correction, or suitably adjusting the rotation angle thereby attenuating the level of correction. Such judgment that the highlight and shadow points are erroneous can be derived from the direction of the color solid axis.

Since the color of the color fog can be easily

judged from the inclination of the color solid axis, it is possible not to execute the color fog correction for an image taken for example with a color filter for obtaining special effect.

In such situation, the angle between the direction vector of the color solid axis and the luminance axis is used for judging that the color fog correction results in a deterioration of the image, and the correction is not executed or is weakened in the level. For example, if the color solid axis is directed toward red and is inclined in excess of a predetermined angle, for example 40°, such image is judged to inherently contain a color fog. The color fog correction with a weakened level can be achieved, for example, by raising the color solid axis by a predetermined angle, for example by 20°, or to a predetermined angle, for example an angle of 20° to the Y-axis. The rotation matrix for such conversion can be easily determined from the rotation axis and the rotation angle.

The level of the above-mentioned correction can be manually designated by the user, or set in advance according to the magnitude of angle and the direction of the color solid axis. In the foregoing description the color solid of the image showing an inclination of 40° is raised by rotation by 20°, but the level of such correction may be designated by the user. The succeeding process is same as in the first embodiment.

Also, as the color of the color fog can be easily judged from the direction of the color solid axis, it is possible, for example, not to execute correction in the direction of the color of filter, for an image taken with a color filter for obtaining a special effect. In such case, there is designated a color for which the color fog is not corrected, then, a rotation axis for conversion is set along the non-corrected color on the C1-C2 plane and the color solid is rotated until a plane containing such rotation axis and the color solid axis 1 becomes parallel to the Y-axis. Such method allows to correct the color fog only for the specified color components.

Fig. 10 is a flow chart showing a sequence for image correction by rotating the color solid to a separately designated angle in case the color solid angle is inclined at least by a predetermined angle. At first a step S101 determines the highlight and shadow points, and a step S102 discriminates whether the color solid axis is inclined at least by a predetermined angle. If it is less than the predetermined angle, steps S104, S105 correct color fog by such conversion as to bring the color solid axis to the luminance axis, as in the first embodiment.

On the other hand, if the color solid axis is inclined by at least the predetermined angle, a step S103 determines a rotation matrix for rotating the

color solid axis by 20° toward the luminance axis, and a step S105 executes color fog correction by rotating the color solid with such rotation matrix. In this process, the angle 20° employed in the step S103 may be altered arbitrarily.

It is also possible to set threshold values at two levels, and, if the inclination of the color solid axis is larger than a first threshold value (for example 40°), to rotate the color solid axis thereby raising it (for example 20°) to a not completely gray level. If the inclination is between the first and second threshold values (for example 20°), the conversion by rotation is not executed, and, if the inclination is less than the second threshold value, the conversion is executed in such a manner that the color solid axis coincides with the luminance axis. Such method allows to avoid defective correction for the image having intentional color fog.

As explained in the foregoing, it is possible to set at least two threshold values for correction based on the inclination of the axis, namely the direction and angle thereof, of the color solid constituted by the pixels of the image data, thereby judging whether the image correction is to be executed, not to be executed or executed with an adjusted level, thus excluding the defects of the special case in a very simple manner.

It is also possible not to correct the color fog
in a specified color, since the color of the color fog
can be easily judged from the direction of the solor
solid axis.

5   [Third Embodiment]

In the foregoing first to third embodiments, there
has been explained the color balance correction based
on the highlight and shadow points of the image.   In
the following there will be explained an embodiment of

10   the correction on other reference points.

At first there is determined the average color
difference ΔE at the highlight and shadow points by the
following equation:

$$\Delta E = sqrt((C1HL - C1SD)\verb|^|2 + (C2HL - C2SD)\verb|^|2)$$

15   ΔE should be zero if the color solid axis is
parallel to the luminance axis, but becomes larger than
0 if it is inclined.   Fig. 8 shows this relation on an
E (saturation) - Y (luminance) plane.

Then several sample luminances are selected

20   between the highlight and the shadow, and the average
color difference is determined as shown in Fig. 8, for
the pixels having a luminance Yn in the image and
having a saturation smaller than ΔEn. ΔEn may be a
predetermined saturation or the average color

25   difference limited to the direction of inclination of
the color solid axis.

Then a line is determined by the least square

method on the average color difference of these several points, and the process of the first embodiment is executed, taking such line as the color solid axis.

Otherwise there may be executed non-liner color balance correction by determining a B-spline curve approximating the points having the determined color difference and luminance and taking such curve as the luminance axis thereby bringing the color difference to zero.

In this manner the line constituting the luminance axis can be obtain not from the highlight and the shadow only but from the pixels uniformly sample from the entire image. Thus the color fog correction reflecting the characteristics of tue entire image can be achieved by converting the image in such a manner that thus obtained line coincides with the luminance axis.

The present invention has been explained by preferred embodiments thereof, but the present invention is not limited by such embodiment and is subjected to various modifications within the scope and spirit of the appended claims.

[Other Embodiment]

The present invention may be applied to a system consisting of plural equipment (for example host computer, interface devices, reader, printer etc.) or an apparatus consisting of a single equipment (such as

a copying machine or a facsimile apparatus).

Also the objects of the present invention can be attained in a case where a memory medium storing program codes of sequences shown in Figs. 3, 4, 9 and 10 is supplied to the system or apparatus and a computer (or a CPU or an MPU) of the system or the apparatus reads and executes the program codes stored in the memory medium.

In such case the program codes themselves read from the memory medium realize the functions of the aforementioned embodiments, and the memory medium storing such program codes constitutes the present invention.

The memory medium storing such program codes can be, for example, a floppy disk, a hard disk, an optical disk, a magnetooptical disk, a CD-ROM, a CD-R, a magnetic tape, a non-volatile memory card or a ROM.

The present invention includes not only the case where the computer executes the read program codes to realize the functions of the aforementioned embodiments but also a case where an operating system or the like functioning on the computer executes all the actual process or apart thereof under the instruction of the program codes; thereby realizing the functions of the aforementioned embodiments.

The present invention further includes a case wherein the program codes read from the memory medium

are once stored in a memory provided in a function

expansion board of the computer or a function expansion

unit connected to the computer, and a CPU or the like

provided in the function expansion board or the

5   function expansion unit executes all the process or a

part thereof according to the instructions of such

program codes, thereby realizing the functions of the

aforementioned embodiments.